M.E. Ph.D. Qualifier Exam
FALL Semester 2001

GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam - FALL Semester 2001

DESIGN
EXAM AREA

Assigned Number (DO NOT SIGN YOUR NAME)

- **Please sign your name on the back of this page—**

GEORGE W. WOODRUFF SCHOOL OF MECHANICAL ENGINEERING
GEORGIA INSTITUTE OF TECHNOLOGY

DESIGN QUALIFIER

FALL 2001

WRITTEN EXAMINATION

We are interested in learning what you know and your ability to reason in the formulation and solution of design problems.

If you find any question or part of this exam confusing, please state your assumptions and rephrase the question.

Please read the entire exam first. Allocate your time carefully so that you cover all three parts that you are being examined on in these two questions, namely, Methods, Realizability and Analysis.

ORAL EXAMINATION

Please arrive half an hour before the scheduled time for the oral exam. During this period we will give you a question to think about. The scope of the oral exam is as follows:

- provide an opportunity for you to state how design fits into your research activities;
- probe your understanding of the question that we posed to you in the preceding half hour;
- reexamine elements of the written exam.

QUESTION 1 – METHOD & REALIZABILITY

Scenario

You have been recently hired at XYZ High-Speed Manufacturing, Inc. The company makes manufacturing machines for high-speed assembly of electronic components. The main product line is a xyz gantry style manipulator. The machine has linear actuators that move in the x, y, and z direction so that the machine can pick and place the electronic components. See Figure 1. The speed of the robotic manipulators is limited by the inertia of the machine. For example, when the machine is moved in the y direction, the entire assembly for moving in the x and z directions must be moved.

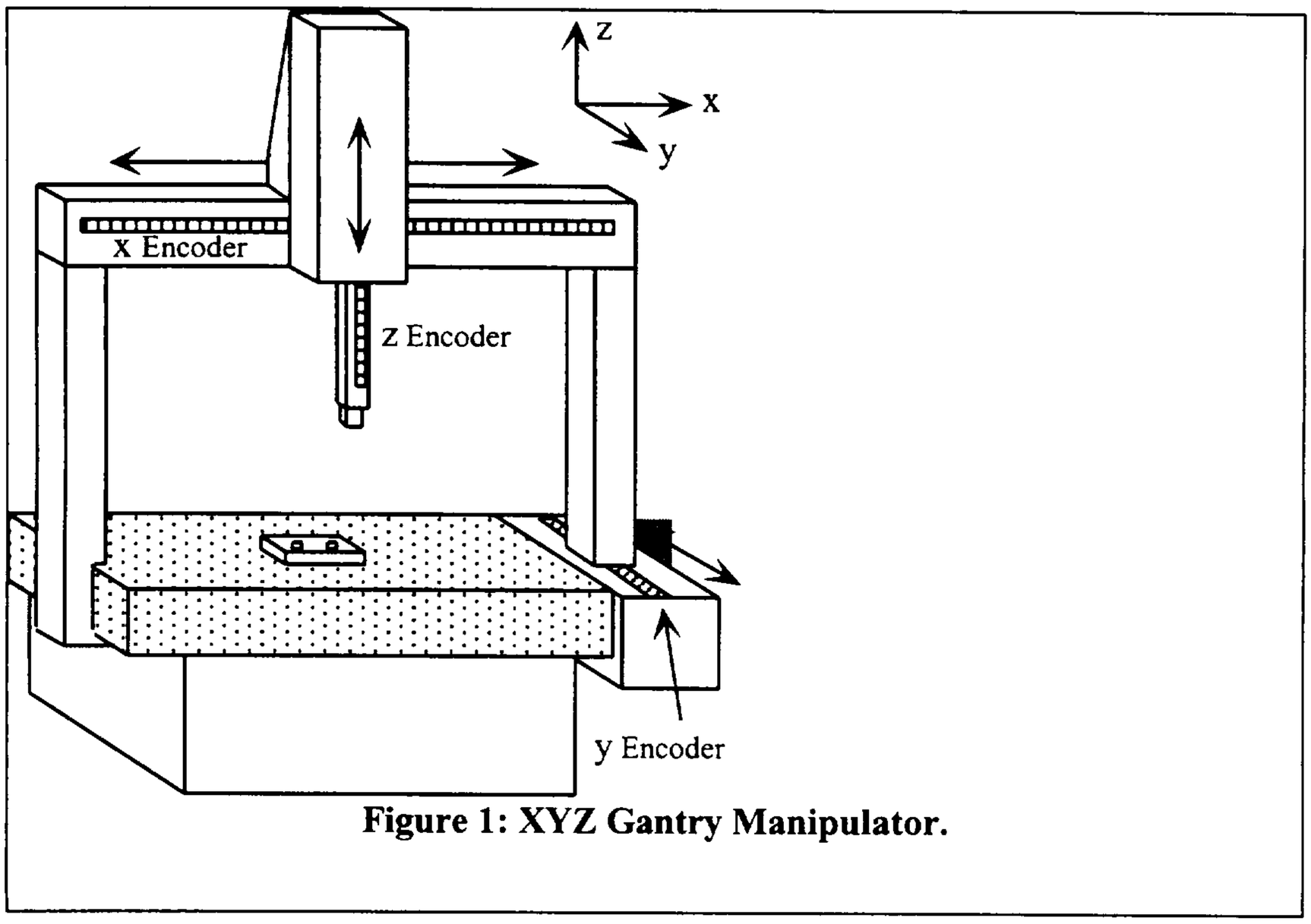

Figure 1: XYZ Gantry Manipulator.

Recently, a new concept has been proposed for greatly reducing the inertia barrier - wire driven manipulators. With these devices the payload is supported by wires and motion is accomplished by shortening and lengthening the suspension wires. With this type of system, the moving inertia of the machine can be reduced to near zero. Unfortunately, the workspace of the initial prototype that XYZ, Inc. has developed is very limited and the vibration in the suspension wires makes accurate positioning very difficult.

Goal

Your job is to develop a new design for a wire-driven manipulator. Your boss wants you to start from scratch and document your design process thoroughly. A senior engineer has suggested that you follow the general guidelines given below and turn in a report documenting the five steps.

Deliverables

Method

1. Clarify the Task: State the overall function of your system.

2. Conceptual Design: State and implement the steps (including a specification list and functional diagrams/decomposition) for transforming the overall function that you have identified into at least three alternative design solutions. Sketch and describe the workings of these alternatives.

3. Use a structured approach to select one of the alternatives for further development.

Realizability

4. Further develop the alternative that you have selected.

5. Critically evaluate the design in terms of manufacturability, initial cost, maintenance cost, reliability, manipulation performance, and other criteria that you feel are important to consider in this phase of design.

Your Exam #: .....

QUESTION 2 – ANALYSIS

You MUST write your solutions to QUESTION 2 on this exam sheet.

2A. A 6309 single-row deep groove ball bearing, which is operating at 1500 rpm, is acted on by 1890 lb radial load and a 1250 lb thrust load. The inner ring rotates, the load is steady, and the service is continuous. Determine the rating life.

Factors V, X, and Y for Radial Bearings

Bearing Type			In Relation to the Load the Inner Ring is		Single Row Bearings 1)		Double Row Bearings 2)				e
			Rotating	Stationary	$\frac{F_a}{VF_r} > e$		$\frac{F_a}{VF_r} \leq e$		$\frac{F_a}{VF_r} > e$		
			V	V	X	Y	X	Y	X	Y	
3)	4) $\frac{F_a}{C_0}$	5) $\frac{F_a}{iZD_w^2}$									
Radial Contact Groove Ball Bearings	0.014	25				2.30				2.30	0.19
	0.028	50				1.99				1.99	0.22
	0.056	100				1.71				1.71	0.26
	0.084	150				1.55				1.55	0.28
	0.11	200	1	1.2	0.56	1.45	1	0	0.56	1.45	0.30
	0.17	300				1.31				1.31	0.34
	0.28	500				1.15				1.15	0.38
	0.42	750				1.04				1.04	0.42
	0.56	1000				1.00				1.00	0.44
20°			1	1.2	0.43	1.00	1	1.09	0.70	1.63	0.57
25°					0.41	0.87		0.92	0.67	1.44	0.68
30°					0.39	0.76		0.78	0.63	1.24	0.80
35°					0.37	0.66		0.66	0.60	1.07	0.95
40°					0.35	0.57		0.55	0.57	0.93	1.14
Self-Aligning Ball Bearings			1	1	0.40	0.4 cot α	1	0.42 cot α	0.65	0.65 cot α	1.5 tan α
Self-Aligning and Tapered Roller Bearings			1	1.2	0.40	0.4 cot α	1	0.45 cot α	0.67	0.67 cot α	1.5 tan α

For two single row angular contact ball or roller bearings mounted "face-to-face" or "back-to-back" the values of X and Y which apply to double row bearings. For two or more single row bearings mounted "in tandem" use the values of X and Y which apply to single row bearings.

2) Double row bearings are presumed to be symmetrical.

3) Permissible maximum value of $\frac{F_a}{C_0}$ depends on the bearing design.

4) C_0 is the basic static load rating.

5) Units are pounds and inches.

Values of X, Y and e for a load or contact angle other than shown in the table are obtained by linear interpolation.

$F_e = VF_r$

$F_e = XVF_r + YF_a$

where:
F_e = equivalent load
F_r = radial load
F_a = axial load

$C = F_e L^{\frac{1}{a}}$

for ball bearings: a = 3
for roller bearings: a = 10/3

2B. Please write a short complete descriptive answer in the space provided.

a. Explain the meaning of L_{10} life.

b. Explain the meaning of basic load rating (dynamic load rating).

c. Compare and contrast ball bearings and roller bearings in terms of speed and load carrying capabilities.

d. List two primary reasons why bearings fail.

e. List two special considerations when specifying rolling element bearings, besides Life.

f. Explain what happens when the static load capacity is exceeded.

g. For a helical extension spring, what do we mean when we say that the end is a standard end?

h. Is buckling an issue with extension springs? Please explain.

i. Why are the ends of torsion spring coils extended tangentially?

j. Why should the applied moment in a torsion spring be arranged to close the coils rather than open them?

k. For static failure (yielding) of a torsion spring loaded to close its coil, which stress will be of most concern, and where does it occur?

l. For fatigue failure of a torsion spring loaded to close its coil, which stress will be of most concern and why? Where does this stress occur?

m. Explain how an involute is generated, and list two reasons why it is the preferred shape for gear teeth.

n. When are gaskets used in joints? Name the two classes of gaskets.

o. Discuss the differences between confined and unconfined gaskets.